Time-lens based synchronizer and retimer for 10 Gb/s Ethernet packets with up to ±1MHz frequency offset

Laguardia Areal, Janaina; Hu, Hao; Palushani, Evarist; Oxenløwe, Leif Katsuo; Clausen, Anders; Berger, Michael Stübert; Jeppesen, Palle

Published in:
2010 Conference on Lasers and Electro-Optics (CLEO) and Quantum Electronics and Laser Science Conference (QELS)

Publication date:
2010

Document Version
Publisher's PDF, also known as Version of record

Time-lens based Synchronizer and Retimer for 10 Gb/s Ethernet packets with up to ±1MHz frequency offset

Janaina L. Areal, Hao Hu, Evarist Palushani, Leif K. Oxenløwe, Anders T. Clausen, Michael S. Berger and P. Jeppesen

DTU Fotonik, Technical University of Denmark, DK-2800 Kgs. Lyngby, Denmark

Janal@fotonik.dtu.dk

Abstract: We present a time-lens based all-optical 10 Gb/s frame synchronizer and retimer. Our scheme can work with a 4096-bit frame, with frequency offset up to 1MHz, which is demonstrated by experimental results.

OCIS codes: (060.2330) Fiber optics communications; (060.1155) All-optical networks; (320.0320) Ultrafast Optics

1. Introduction

For an asynchronous Ethernet network link with a nominal line rate of 10 Gb/s, the repetition rate frequency variation of data packets (data frames) must be within ±100 ppm. This means that up to 1 MHz frequency offset in repetition rate between transmitted data packets and receiver clocks must be tolerated [1]. As data packets may come from various origins, a desired feature of a network node would be the ability to synchronize the arriving data packets to a local clock.

In this paper we analyze a time-lens scheme used for all-optical synchronization and retiming of such optical frames. The time-lens consists of a phase modulator and a dispersive element [2]. The retimer should be able to accommodate for the allowed maximum 1 MHz offset. Our operational conditions assume the extreme case, i.e. frequency offset = 1 MHz, and we demonstrate that we can synchronize a data packet of a length of 4096 bits.

2. 10 Gb/s frame synchronizer and retimer design

Fig. 1 presents (a) a schematic of the time-lens implementation and (b) the operational principle. Two parameters are relevant in this setup. The first one is the initial time misalignment (Δt_0) – defined as the temporal misalignment between the first data pulse maximum and the minimum of the sinusoidal drive signal. The initial time misalignment arises from the asynchronous transmission of frames. The synchronization function consists of aligning the maximum of the input pulse to the minimum of the locally generated sinusoidal voltage. The second parameter is the frequency offset ($\Delta f = f - f_L$) – defined as the difference between the nominal data rate of the data over the fiber (f), and the frequency of the local clock reference (f_L). The retiming function consists of locking the output pulse-position to the local minimum of the local sinusoidal clock. Therefore, the output data pulses will occur in a nominal data rate equal to the local clock frequency.

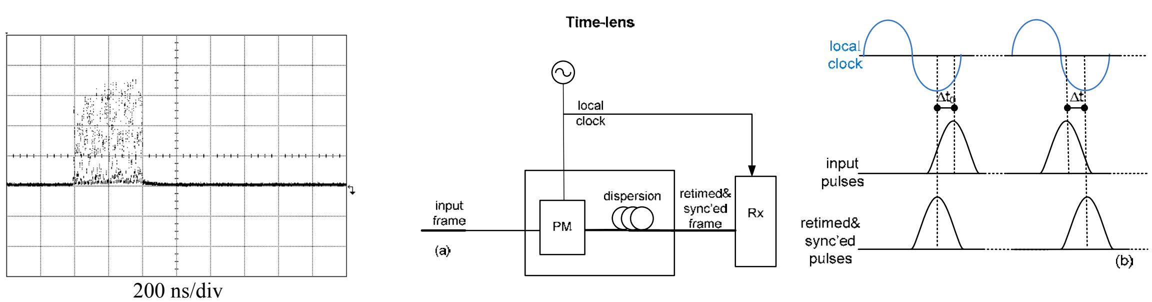


Fig. 1. 10 Gb/s frame retimer and synchronizer. (a) Scheme. (b) Operational principle.

We have recently analyzed the design in Fig. 1(a) for various initial time misalignments and frequency offsets [3]. The time misalignment (Δt) between input pulses and the local clock changes by $\Delta T = 1/f - 1/f_L$ for each successive pulse, i.e. $\Delta t = \Delta t_0 + n\Delta T$. For correct operation, Δt must be such that the phase modulation is approximately a parabolic waveform [2]. This holds for $\Delta t \sim \pm 0.2T$ ($T = 1/f$).

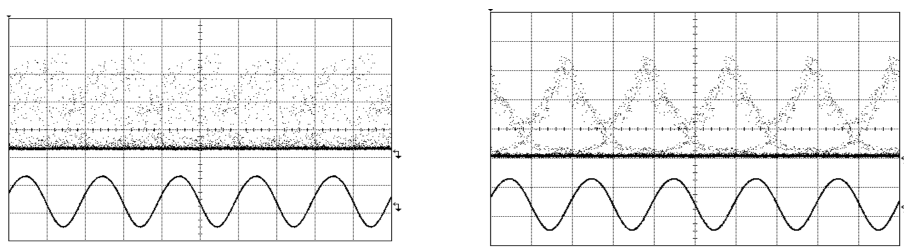
Fig 1(b) shows the case where $\Delta f > 0$. Let $\Delta t_0 = 0.2T$. For Δt varying from $0.2T$ up to $-0.2T$, we have up to $0.4T/\Delta T$ bits being correctly position-locked and aligned to the local clock reference. For $\Delta f = 1$MHz it corresponds to 4096 bits correctly retimed. In the same way, for $\Delta f > 0$, ΔT is positive and Δt should vary from $-0.2T$ up to $+0.2T$, and the same number of bits can be retimed for $\Delta f = -1$MHz. These are the extreme operational conditions

978-1-55752-890-2/10/$26.00 ©2010 IEEE

(maximum modulus for the frequency offset). In such cases, the proposed scheme will always be able to properly retime 4096 bits of the input frame, and for lower offsets longer frames can be synchronized.

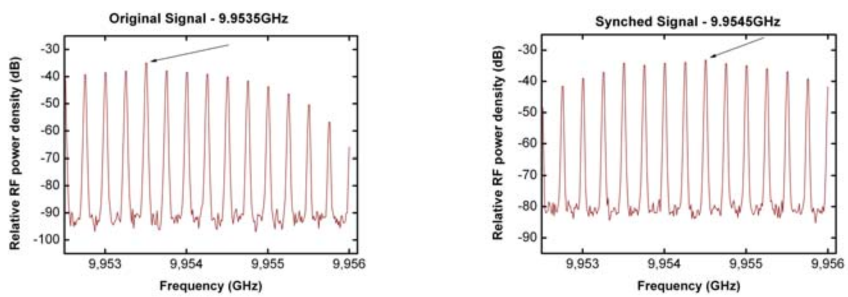
3. Experimental Results

The optical frame is generated from Return-to-Zero (RZ) Gaussian pulses at 1549 nm with a 10 ps FWHM. These are modulated by a 9.9535 Gb/s on-off keying (OOK) signal with a 2^7–1 pseudo-random bit sequence with a 4096 bits frame length. The local clock (f_L) is 9.9545 GHz. The synchronization and retiming unit is represented by an optical phase modulator (PM) with a driving voltage of Vpp = 2.7 Vπ and the dispersive element is 4 km of SMF with 17 ps/nm/km dispersion, using the design parameters reported in [2]. Fig 2 (a) shows the eye diagram of the original signal and (b) the synchronized and retimed signal, triggered by the local clock (f_L). Before synchronization and retiming, the original optical frame is not resolved by the oscilloscope. After the synchronization and retiming, a clear eye diagram can be seen using the local clock as the trigger, thus clearly demonstrating that the data frame is now in sync with the local clock. Fig. 3 (a) and (b) show the original and synchronized/retimed spectrum of the optical frame. In the RF spectrum of the original optical frame, the peak frequency in Fig. 3 (a) is the original clock frequency (9.9535 GHz). After the synchronization and retiming, the peak frequency is shifted to that of the local clock (9.9545 GHz), in Fig. 3 (b).



50 ps/div (a) 50 ps/div (b)

Fig. 2. Experimental results for a 4096 bit frame. (a) Eye diagram - Original. (b) Eye diagram –Synchronized/Retimed.



(a) (b)

Fig. 3. Experimental results. (a) RF Spectrum – Original (b) RF Spectrum – Synched/Retimed.

4. Conclusions

We have experimentally proposed and evaluated an optical time-lens scheme for synchronization and retiming of asynchronous 10 Gb/s frames. The proposed design is able to synchronize and retime 4096-bit frames even in the presence of ±1MHz frequency offset.

5. Acknowledgment
We would like to thank the Danish Research Council for supporting the project NOSFERATU (Non-linear optical switching for extremely high data rate communications).

6. References

[1] IEEE 802.3ae – Amendments, Parameters for 10 Gb/s Operation, 2002.
[2] B. H. Kolner and M. Nazarathy, "Temporal imaging with a time lens," Opt. Lett. 14, 630-632, 1989.
[3] J. Areal, H. Hu , C. Peucheret , E. Palushani , R. Puttini , A. Clausen , M. Berger , A. Osadchiy and L. Oxenløwe, "Analysis of a Time-lens based Optical Frame Synchronizer and Retimer for 10G Ethernet Aiming at a Tb/s Optical Router/Switch Design", accepte*d by ONDM 2010.*